GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 9/30/78

Project Title: Cloud-Detecting Nephelometer

Project No: G-35-642 Green Card

Project Director: Dr. G. W. Grams

Sponsor: University of Denver (Colorado Seminary); Denver, Colorado 80208

Agreement Period: From 6/15/78 Until ~~10/15/78~~ 30 Jun 79

Type Agreement: Subcontract dated 8/23/78 (Reference P.O. No. 11686) under DASG60-78-C-0042
Contracted thru GTRI

Amount: $16,652

Reports Required: Final Report

Sponsor Contact Person (s):

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Defense Priority Rating: n/a

Assigned to: School of Geophysical Sciences (School/Laboratory)

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CA—3 (3/76)

GEORGIA INSTITUTE OF TECHNOLOGY
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SPONSORED PROJECT TERMINATION

Date: December 21, 1979

Project Title: Cloud Detecting Nephelometer

Project No: G-35-642

Project Director: Dr. G. W. Grams

Sponsor: University of Denver (Colorado Seminary)

Effective Termination Date: 6/30/79

Clearance of Accounting Charges: 6/30/79

Grant/Contract Closeout Actions Remaining:

X Final Invoice ~~and Closing Documents~~
_ Final Fiscal Report
_ Final Report of Inventions
_ Govt. Property Inventory & Related Certificate
_ Classified Material Certificate
_ Other ______

Assigned to: School of Geophysical Sciences (School/Laboratory)

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CA-4 (1/79)

G-35-642

CLOUD-DETECTING NEPHELOMETER

Final Report to Denver University for
Subcontract under Prime Contract No. DASG60-68-C-0042
between the U.S. Army and DU

Principal Investigator:

Prof. Gerald W. Grams
School of Geophysical Sciences
Georgia Institute of Technology
Atlanta, Georgia 30332

Period covered:

15 June 1978 to 30 June 1979

ABSTRACT

A fixed-angle nephelometer was installed as part of a stratospheric balloon package and flown in a series of experiments in Alaska during late Summer 1978. The purpose of the nephelometer experiment was to monitor the environment in the vicinity of the balloon to determine whether or not nacreous clouds were present and to provide estimates of the cloud concentration for use in the interpretation of data obtained by other sensors that were operated simultaneously on the balloon platform. The cloud-detecting nephelometer was operated on each of four balloon flights in Alaska during the time period from 31 August 1978 to 12 September 1978.

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BACKGROUND INFORMATION

Interest in stratospheric particulates began nearly a century ago with investigations into noctilucent clouds, nacreous (mother-of-pearl) clouds, and various twilight effects thought to be caused by the presence of dust in the upper atmosphere. The Krakatoa eruption in 1883 demonstrated that volcanic dust could be injected into the stratosphere, and a significant amount of literature since that time has been concerned with methods of quantitatively determining the aerosol content of various layers of the atmosphere (Harris, 1971). Research on stratospheric particles has accelerated during the past decade because of concern that man's activities may be increasing the average concentration of stratospheric particulates. Increased recognition of the significance of stratospheric aerosols as an atmospheric constituent has been documented in several recent publications (e.g., Rosen, 1969; Reiter, 1971; Castleman, 1974; Cadle and Grams, 1975; Grams and Rosen, 1978).

The principal investigator has carried out observational and analytical studies of the stratospheric aerosol layer since the early 1960s. In addition, his Atmospheric Optics Group in the School of Geophysical Sciences at Georgia Tech has developed in-situ instrumentation and data analysis techniques for characterizing the optical properties of airborne particulates for use in calculations of the effects of atmospheric aerosol layers on the earth's radiation balance and for use in the interpretation of data obtained by remote optical probing techniques.

In 1975, the principal investigator began to use an adaptation of the design of a compact backscattering nephelometer that was originally meant to be used to study the vertical structure of cloud layers in the atmosphere of Venus as a part of the Pioneer Venus Multiprobe Mission (Colin and Hall, 1977; Colin and Hunter, 1977). A modified version of the cloud-detecting nephelometer was constructed, tested, and flown on the NCAR Sabreliner and Electra atmospheric research aircraft in a number of field measurement programs.

In 1977, discussions between the principal investigator and Dr. D. G. Murcray of the University of Denver resulted in an effort to modify the airborne cloud-detecting nephelometer for operation on a high-altitude balloon platform.

Earlier observations of the infrared solar spectrum by University of Denver balloon-borne interferometer systems in Alaska suggested the possibility that nacreous clouds may have been present during some of their high-latitude balloon observations. Other interpretations of the infrared observations included the possibility that ice crystals or other types of suspended particulates could be formed by condensation of air that had been cooled by the equipment itself. As a means of establishing whether or not the balloon package was in a nacreous at any particular time, Georgia Tech's Atmospheric Optics Group agreed to perform the following tasks for the University of Denver:

(1) Modify and test an existing cloud-detecting nephelometer for operation over the range of ambient conditions expected during balloon flights scheduled during late August and early September 1978.

(2) Install the nephelometer on the Denver University balloon package prior to the field measurement program.

(3) Monitor the operation of the nephelometer in Alaska during the balloon flights.

(4) Analyze and interpret data obtained with the nephelometer after the balloon flights were completed.

INSTRUMENTATION

Our balloon-borne instrument was based on the design of a compact device developed for the Pioneer Venus multiprobe mission. Cloud-structure data obtained with nephelometers mounted on probes which descended through the atmosphere of Venus at four different locations have been described in the scientific literature (Ragent and Blamont, 1979; Blamont and Ragent, 1979).

Figure 1 is a drawing which illustrates the basic configuration of the

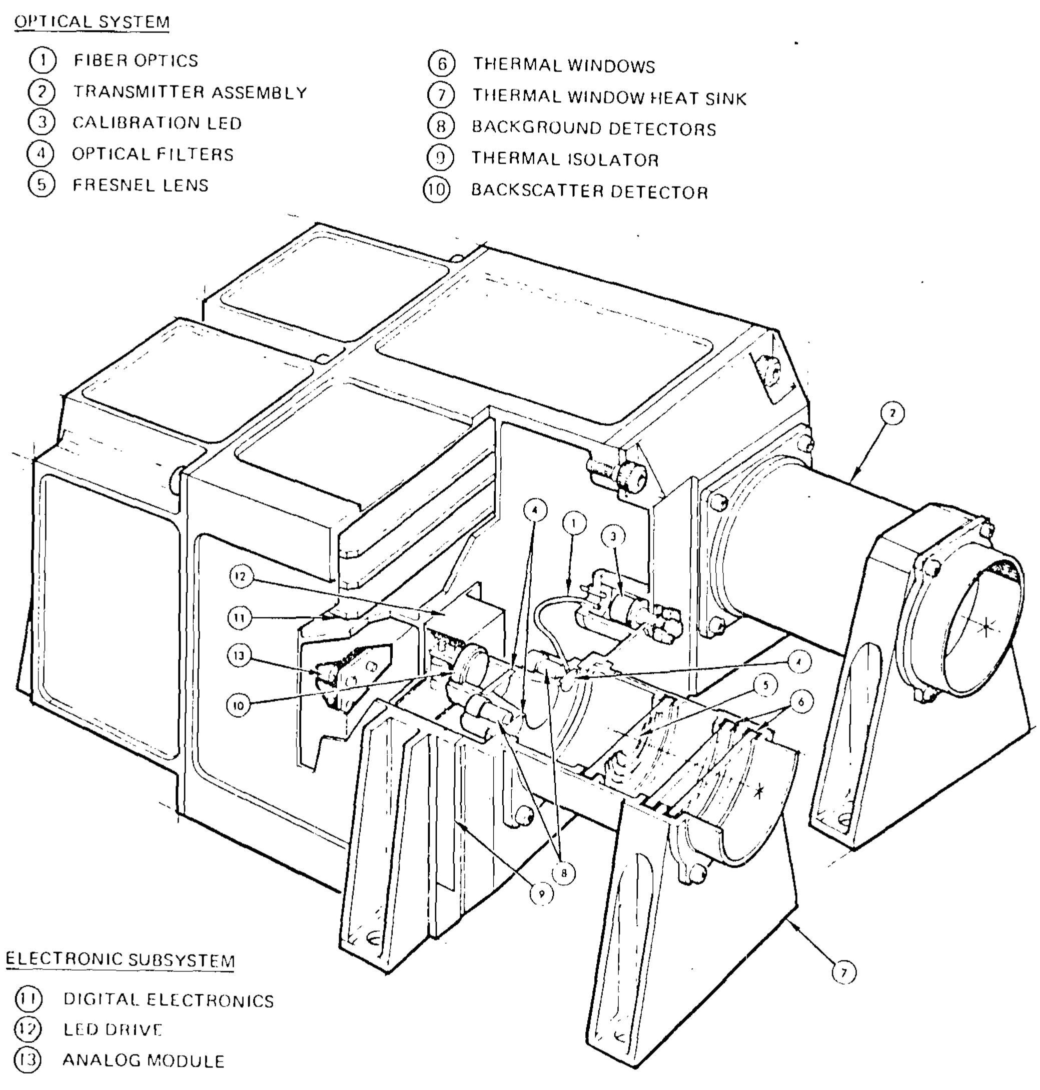

Fig. 1. Example of Construction Used for the Pioneer Venus Nephelometers.

Pioneer Venus nephelometers. The actual appearance of the airborne unit that was developed for use on research aircraft and then further modified for the University of Denver balloon study is slightly different from the space probe instrument, but the overall concept of the instrument and the principal of operation is identical to the devices flown on the Pioneer Venus multiprobe mission. The airborne nephelometer that was modified for the present study had been flown and used for several hundred hours on the NCAR Electra and Sabreliner research aircraft to detect the presence of clouds and to indicate variation in cloud particle concentrations with high temporal resolution in a number of different atmospheric measurement programs.

The major components of the cloud nephelometer are the transmitting and receiving assemblies. The transmitter uses a pulsed light emitting diode which radiates optical pulses at approximately 0.93 μm wavelength. A 2.5-cm diameter Fresnel lens is used to collimate the output radiation. As light pulses from the transmitter propagate through the atmosphere, a small fraction of the incident radiation will be scattered in all directions by air molecules and suspended particulate material. The receiver subsystem utilizes a Fresnel lens to collect radiation backscattered at angles of approximately 175° from the direction of propagation; the collected radiation is then focussed onto a solid state detector.

With regard to the modified balloon-borne cloud detecting nephelometer used for the Alaska experiments, the transmitter incorporated a Texas Instruments* Type TIA16 high-power GaAs infrared radiation source which emitted 10-nsec pulses with peak powers of approximately 200 mW at a pulse repetition frequency of 10 kHz. Unfortunately, the angular dispersion of the emitter is quite large, and it was possible to collimate about one-half of the total emitted power; thus, the effective output power of the transmitter was only about 100 mW. We increased the sensitivity of the system by adding a second receiver with a 10-cm Fresnel lens to supplement the 2.5-cm diameter receiver used in our original airborne cloud nephelometer. Signals from both the 2.5-cm and the 10-cm receiver were recorded during each mission. The detector used on the 10-cm diameter receiver was a Texas Instruments* Type TIED59 silicon avalanche photodiode with an active area of 4.5×10^{-3} cm^2 (diameter = 0.75 mm) and a system noise-equivalent-power spectral density of 2×10^{-13} W/$\sqrt{\text{Hz}}$.

*Texas Instruments
P. O. Box 5012
Dallas, TX 75222

RESULTS

During August 1979, the principal investigator and Mr. Clyde Wyman of the Georgia Tech's Atmospheric Optics Group installed the nephelometer on the Denver University balloon package. Prior to the installation, a series of tests were performed on the instrument in an environmental chamber operated by NCAR's Field Observing Facility in Boulder, Colorado. A series of laboratory measurements were performed for calibration purposes at Denver University. The equipment was then installed on the balloon package and prepared for shipment to Alaska. Mr. Wyman accompanied the Denver University balloon-launch team to Fairbanks and operated the cloud nephelometer during the field measurement program.

The instrument was successfully operated on each of the four balloon flights that were made during the Summer 1978 field measurement program on August 31, September 4, September 8 and September 12. A schematic drawing of the location of the nephelometer on the balloon platform is shown in Fig. 2.

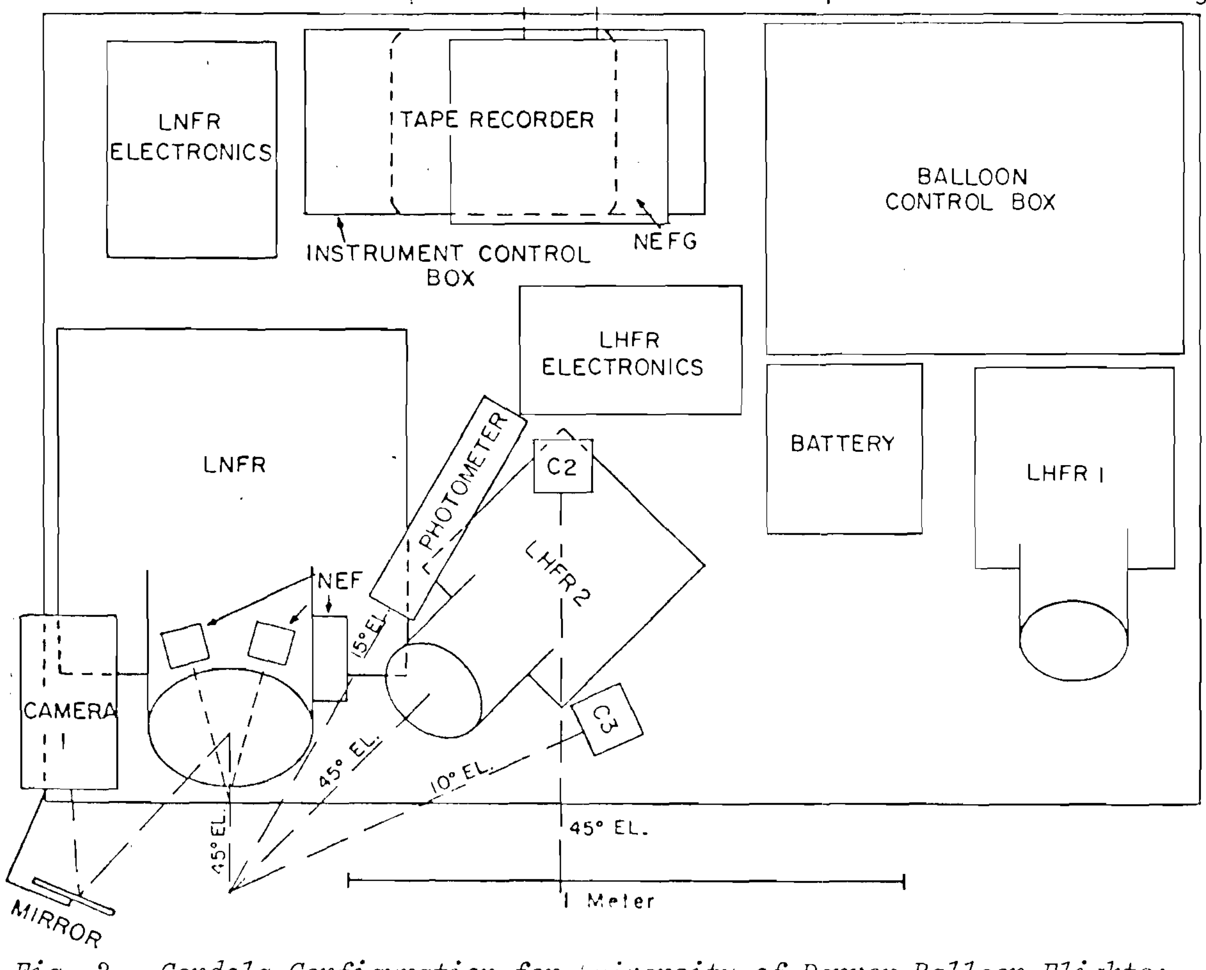

Fig. 2. Gondola Configuration for University of Denver Balloon Flights; the location of the cloud nephelometer is denoted by the word "NEFG."

The transmit and receiver assemblies were adjusted to detect echoes from a continuous volume ranging from 2 to 10 meters from the balloon gondola.

Fig. 3 shows altitude-versus-time profiles for the series of balloon

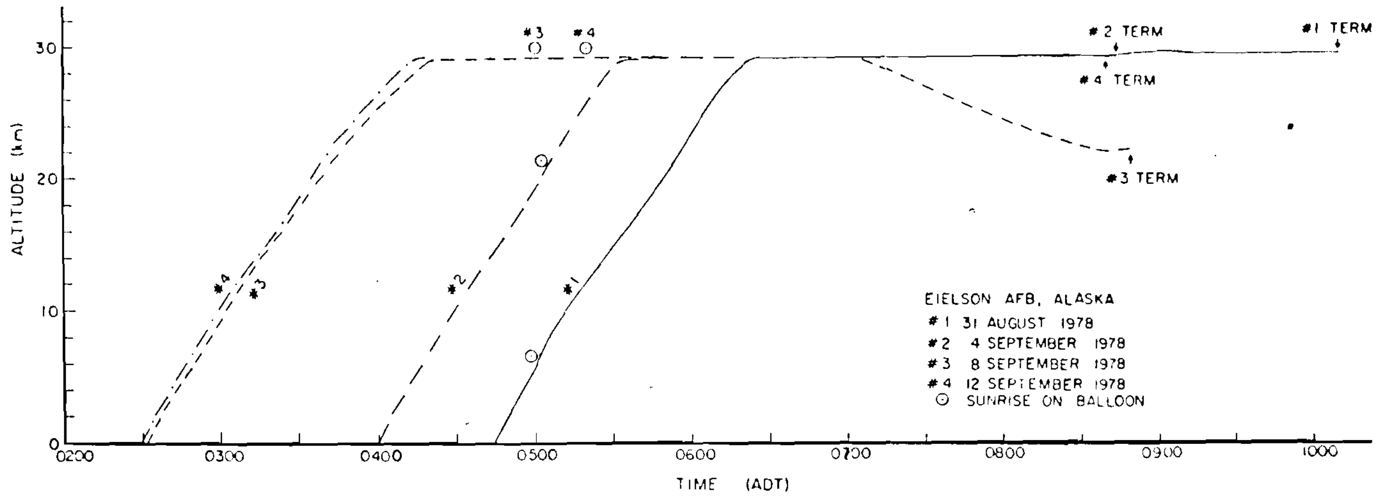

Fig. 3. Altitude Versus Time Profiles for Each of the Four Balloon Flights.

flights made in Alaska during late Summer 1978. The nephelometer results were recorded by the Denver University data acquisition system which digitized analog voltages from the nephelometer and recorded the results of all the balloon instruments onto magnetic tape; the nephelometer voltages are directly proportional to the 175° backscattering cross-section of the atmosphere (including air molecules as well as particulate materials).

As a design goal, it would have been desirable to increase the sensitivity of the cloud nephelometer to the point at which it would record molecular backscattering at the highest altitudes (e.g., at ∿30 km). In that case, any particulates that backscattered an amount of light that exceeded echoes from air molecules would be detected by the system. However, the cost and the time required to develop such an instrument would have been prohibitive. Furthermore, that level of sensitivity would probably not be necessary since scattering cross-sections of ice crystals and other cloud particles are expected to be appreciably higher than molecular scattering cross-sections. In fact, laser radar observations of thin cirrus clouds at the wavelength 0.6943 μm by SRI International (Dr. P. B. Russell, private communication) have demonstrated that backscattered signals from subvisible cirrus clouds will exceed molecular scattering cross-sections when particle concentrations are some 2 orders of magnitude less than those associated with cirrus clouds that can be observed visually.

For the present report, our studies of the data have been based on strip chart records of the output of the nephelometer channel for the 10-cm receiver, as recorded by the University of Denver balloon-launch team at the Alaskan site during each of the four balloon flights described above. The records indicate that the nephelometer performed in accordance with our expectations. Visual inspection of the strip chart records indicated that the nephelometer was able to record atmospheric backscattering signals in the troposphere. The signals dropped to system-noise levels before the balloon reached float altitudes where molecular number densities (and therefore the molecular backscattering cross sections) are almost 2 orders of magnitude lower than the corresponding values at the surface. Based on the strip chart records, we did not obtain any evidence for the presence of nacreous clouds at float altitudes.

We are quite interested in pursuing the use of the nephelometer to study backscattering from stratospheric aerosol particles on high altitude balloon platforms. We have requested and we have received a copy of the magnetic tape used by Denver University to record our data during each of the four balloon flights. As part of another sponsored research program at Georgia Tech, we plan to re-analyze the digitized data to evaluate the performance of the nephelometer. This data analysis effort is now underway, and we hope to use the data obtained in the Summer 1978 balloon flights to demonstrate the potential of the instrument for stratospheric aerosol studies. If the results of this effort are encouraging, we plan to prepare a paper on the results of the Alaskan nephelometer measurements and submit the paper for consideration for publication in the scientific literature.

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